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Bridging Between universAAL and ECHONET for Smart Home Environment

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***Abstract*—Ambient Assisted Living (AAL) pursues the issues of how information and communication technology (ICT) is used to support the quality of life of the elderly and disabled people in smart home environment. Among the many AAL solutions, universAAL is one of the most open platforms that provides a holistic and standardized approach for an easy and economic development of AAL services. However, the compatibility with smart home networking systems that are based on ECHONET standard is not supported. Thus, this paper elucidates the bridging in between the universAAL and the ECHONET standard and thereby enable the attainment of novel AAL applications and services for ECHONET-based smart home automation systems.**

***Keywords*—System Integration, Syntax Translation, universAAL, ECHONET, Smart Homes**

1. Introduction

The utilization of information and communication technologies (ICT) in the smart home domain is essential for the development of ambient assisted living (AAL) to support ageing population live independently and actively [1]. AAL spaces that are smart environments centered on human users, are embedded with various interconnecting devices to operate collectively by utilizing information and intelligence that is distributed throughout the infrastructure. AAL spaces are classified in space profiles, each identifying the typical set of devices used in a specific AAL space scenario. AAL spaces that has the ability to be remotely managed is known as one of their important characteristics to perform the similar requirements for use cases in which an elderly person is assisted by the caregivers. The fundamental services characterizing every AAL space such as context information provision and user adaptation can be guaranteed cooperatively from the distributed services provided via the design process to support remote access and management of AAL space. In order to provide better solutions to AAL space with more feasible technology and practical economic, a European research project which is known as universAAL (uAAL) has been launched as an open standards as well as an open platform to realize it [2]. The advantages of this uAAL project is to provide alternative solutions towards elderly and disabled people with ease of deployment, configuration, personalization and the most important is economically affordable.

The objective of this paper is to introduce, explain and discuss the system integration of uAAL and ECHONET in order to improve the information communication network environment of smart nursing space within smart home environment. As stated in [3], integration of uAAL and KNX has been known as widespread Home and Building Automation standard in Europe. This integration has provided interaction facilities with KNX sensor networks to support the features of monitor and control over KNX devices and sends through the uAAL buses. The integration of uAAL and ZigBee with the OSGi platform also simulates general interest for many application domains and its development. This integration makes the ZigBee is separated from the specific adaptation in the uAAL project. It also implements uAAL wrappers for ZigBee home automation devices to provide context events and services in the uAAL platform. Apart from that, Z-wave has some similarities with ZigBee that is developed as a home automation communication specifications. The integration of uAAL and Z-ware is depending on specific vendor devices, unlike the others, which are depending on standard-based technology integration. The integration of uAAL bundle suite has been carried out to connect to different sensor and actuator technologies, however, there is no prior research related to the integration of uAAL and ECHONET. Hence, the motivation of this paper is to investigate, design and implement the integration of uAAL and ECHONET in the smart home environment, i.e., *iHouse*.

The rest of this paper is organized as follows. In Section 2, the research background of uAAL, ECHONET, and smart home environment. An overview of CARESSES project is given in Section 3. Section 4 presents the system integration, which including implementation details and ontology of remote access with a conversation scenario. Finally, our work is summarized in Section 5.

2. Research Background

2.1. universAAL (uAAL)

universAAL (uAAL) stands for universal open platform and reference for ambient assisted living. The core of universAAL platform is built up by the modules in an uAAL Middleware, which can be divided into container, discovery and peering, communication and data representation. In container part, various containers allow the uAAL Middleware logic to be executed in different environments so that the uAAL Middleware can run on computers with plain Java, embedded systems running Open Services Gateway initiative (OSGi), and Android smartphones. The discovery and peering part is responsible

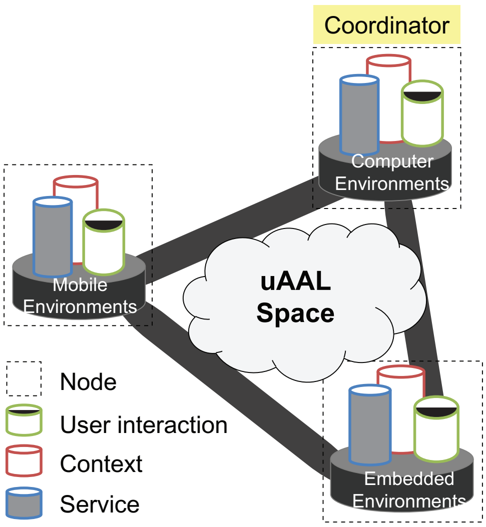

Fig. 1. uAAL open platform

for interconnecting and communicating the instances of the uAAL Middleware regardless of running environment by using technologies such as jSLP (Java Service Location Protocol) and JGroups, which is a reliable group communication toolkit written entirely in Java. The communication part enables the flow of uAAL semantic information across peers by defining specific-purposes buses with ultimate logic of the uAAL Middleware. These buses define what applications connect to, and when they do so, they are in constant contact no matter the device, container or peering technology they are running with.

Figure 1 shows the uAAL open platform. The uAAL Middleware handles all uAAL nodes in a space by establishing peer-to-peer communications between them to share diverse uAAL semantic communication in terms of context, service and user interface (UI) regarding to the shared ontological model. It contains the context-awareness modules, which are including a semantic data and history store, providers of user profiles and AAL space profiles, and generic and specific context reasoner. It also provides the service modules to support the details on how service matchmaking works in the uAAL Middleware, and how it can be used to orchestrate all the services. Moreover, the UI modules that allow defining custom application UI and custom renderers for it. An uAAL Application is the software part of an AAL service, and is understood as a piece of software that communicates with others by making use of the uAAL execution platform. A local device discovery and integration (LDDI) is performed in the uAAL Adaptation according to the design decision and the supported technologies for hardware integration. The LDDI aims at defining an abstraction layer that is able to represent and to facilitate the integration of sensors and actuators into the AAL spaces. The integration of uAAL and ECHONET can be done similarly to the exporters that have been implemented, e.g., KNX, ZigBee, and Z-wave. By doing this, the devices supported by the technologies can be plugged into uAAL and

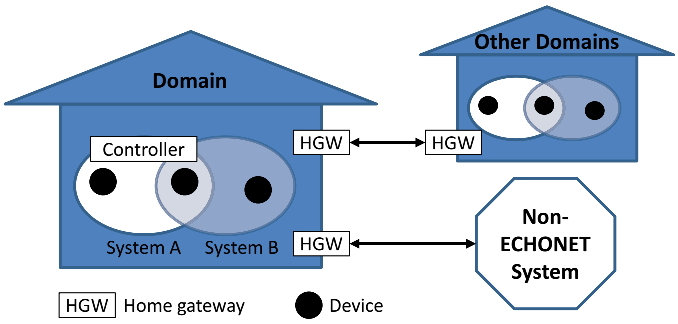

Fig. 2. ECHONET Lite system architecture

making them accessible through the both service and context buses.

2.2. ECHONET

ECHONET is denoted as Energy Conservation and Homecare Network. According to [4], ECHONET consortium has began in December 1997 for systematically enable energy, medical care and security at home in Japan by establishing it in home networks. ECHONET was certified by International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO) and has became a de jure standard since January 2009. The basic system architecture of ECHONET that is illustrated in Fig. 2 consists of a controller accesses to various programmable devices to deliver a notification based on the specified conditions through any communication media. These large amount of devices are modeled as object. However, the ECHONET specification is not universally usable more than ten years due to two major factors. Firstly, the specification requires more complicated system configuration for multiple controllers and multiple devices. Another factor is that the Internet Protocol (IP) address is not considered. In December 2011, ECHONET is therefore redesigned to new ECHONET Lite with the protocol and technology of transmission media as depicted in Fig. 3.

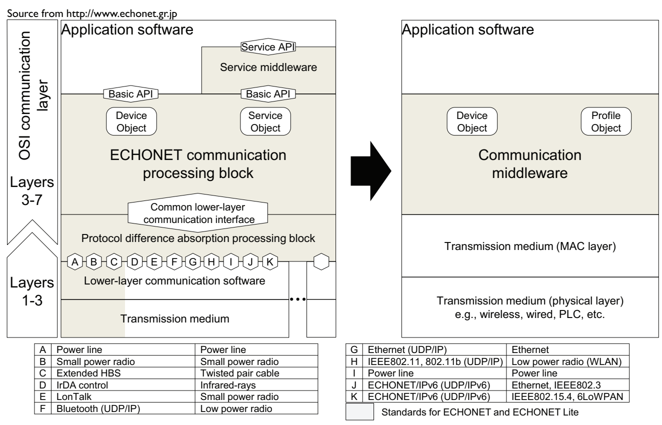

Fig. 3. Standards for ECHONET and ECHONET lite

Fig. 4. Smart home environment: *iHouse*

2.3. Smart Home Environment: iHouse

The term of smart homes had been used by the American Association of House Builders in 1984 as remarked by F.K. Aldrich [5]. The concept of smart homes is to enhance the quality of life (QoL) on providing convenience and comfort, improving safety and security, saving utilities, and improving home care for the elderly and disabled resident.

The current implementation of smart home environment, i.e., *iHouse*, which is shown in Fig. 4. *iHouse* is defined as ishikawa, internetted, inspiring, intelligent House. *iHouse* is an advanced experimental environment for future smart homes in Japan and it has been implemented according to Standard House Design by Architectural Institute of Japan. The location of *iHouse* is built at Nomi city, Ishikawa prefecture. *iHouse* consists of sensors, electronic devices and home appliances that are connecting to each others by utilizing ECHONET Lite version 1.1 and ECHONET version 3.6. This configuration network emanates more than 300 sensors and actuators.

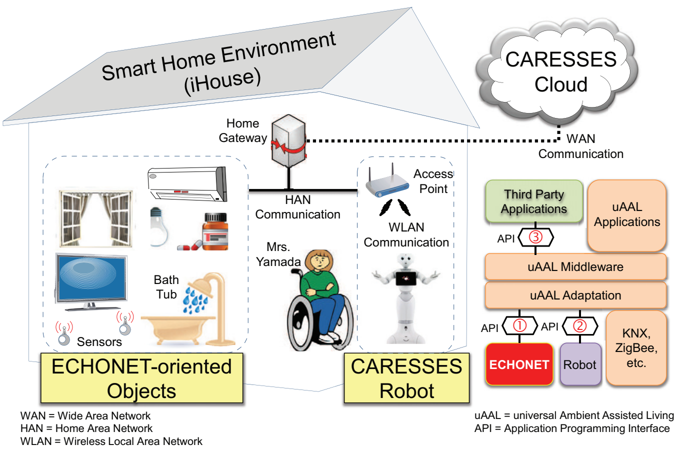

Fig. 5. Overview of CARESSES project with smart home environment

3. CARESSES Overview

CARESSES that stands for "culture aware robots and environmental sensor systems for elderly support" is one of the European Commission-Japan cooperation research and innovation projects from 2017 to 2019 [6]. The primary purpose of CARESSES is to design a culturally aware and competent care robot, which can autonomously act and adaptively say to match the culture, customs and manners of an elderly person. The innovative solutions of CARESSES will offer a safe, reliable and intuitive care robot system, which can support active and healthy ageing with a greater QoL and reduce a caregiver burden with an improved efficiency and efficacy of care service management.

3.1. Concept and Architecture

The key concept of CARESSES can be described by using a scenario, which is illustrated in Fig. 5. A CARESSES robot operates in a smart home environment with the purpose to foster the independence and autonomy of an elderly person, named Mrs. Yamada who is a 75 years old Japanese lady, was diagnosed with thyroid cancer seven years ago, and had a total thyroidectomy. After the medical operation, she has been taking thyroid hormone replacement every morning, she will feels very tired and cold without the hormone. She is staying alone in Kobe while her husband works in Osaka will only stays with her during weekends, her son and daughter are both married and live in Tokyo. Due to one of the effects from the medical operation, she sometimes feels depression and misses her family more than usual. Hence, her husband recently suggested her to stay in a care facility during weekdays where she moved in. In the care facility, the CARESSES robot will take care on her daily life during weekdays as well as monitoring her hormones and physical condition tracking with her doctor in Tokyo.

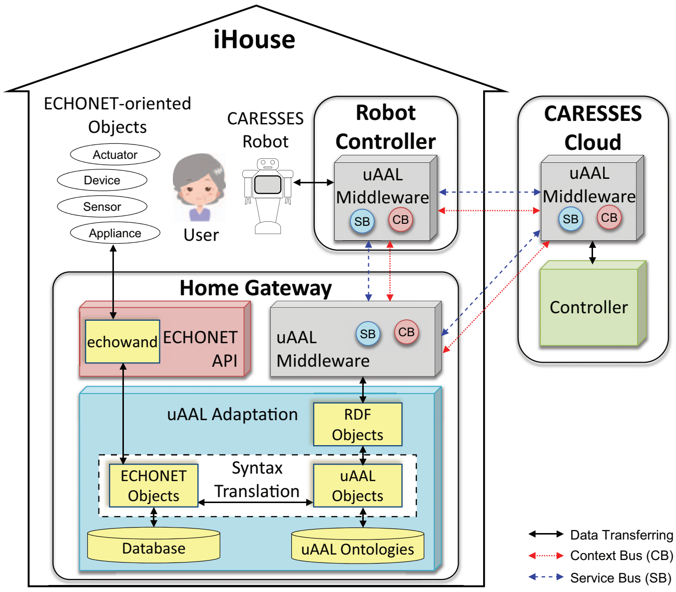

Fig. 6. Overall system architecture

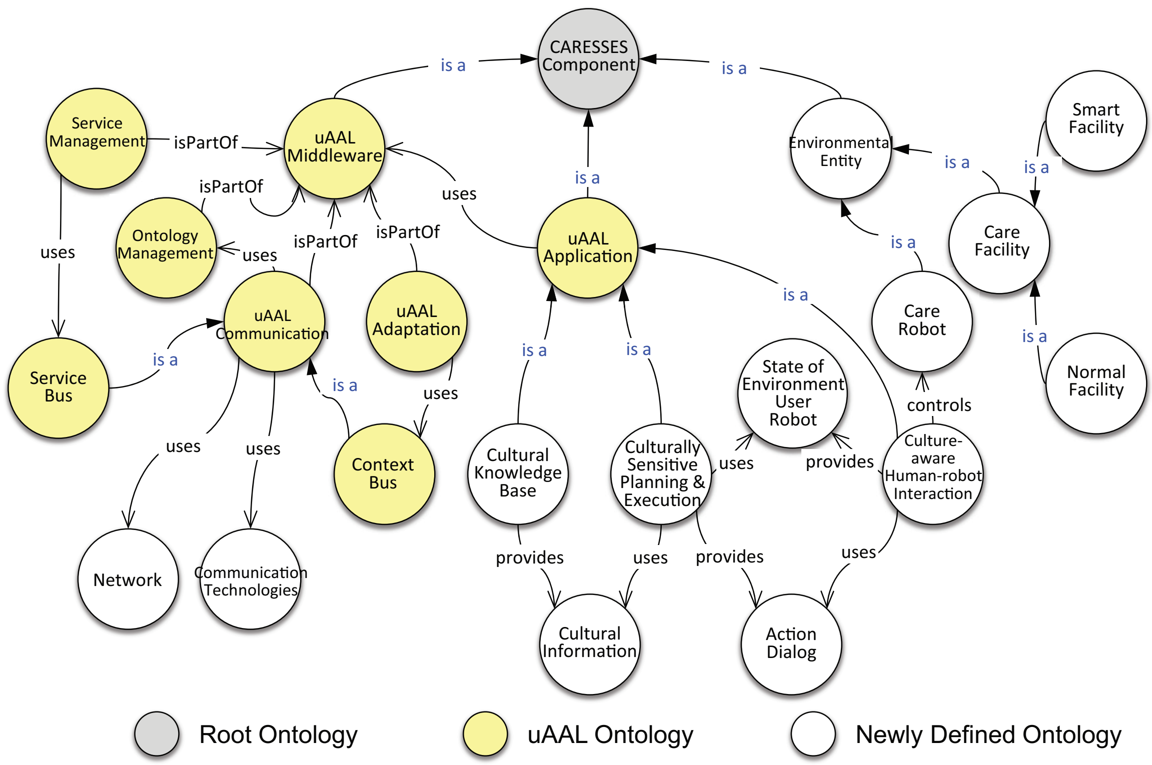

Fig. 7. Skeleton ontology of CARESSES project

To realize the concept of CARESSES project, Fig. 6 shows the overall system architecture. CARESSES project selects open platform uAAL in order to support a seamless integration of heterogeneous sensors, devices, home appliances, robots and user interfaces that handled by different operating systems and communication protocols within the same framework. To that purpose, an uAAL Middleware is required to be installed into each nodes, i.e., home gateway, robot controller and CARESSES cloud for this project. In order to bridge in between uAAL and ECHONET, an uAAL Adaptation is designed and introduced. The uAAL Adaptation composes of a syntax translation, database, uAAL ontologies and resource description framework (RDF) objects. Besides that, an ECHONET Application Programming Interface (API) with echowand library is needed to allow the ECHONET-oriented objects to be interacted by the uAAL Adaptation.

3.2. *Skeleton Ontology*

Ontology is a formal representation vocabulary of the concepts and relationships in a specified domain of knowledge [7]. More precisely, the ontology in this CARESSES project is an unified way to model semantic information to allow the heterogeneous nodes in the uAAL open platform (uAAL space) understand each other. Figure 7 illustrates the skeleton ontology of CARESSES project. The skeleton ontology is an extension of the original uAAL ontologies by adding more necessary modules that are related to the CARESSES project. The skeleton ontology has three core modules. First core module is called as a cultural knowledge base, which provides information in terms of cultural awareness, knowledge, and sensitivity. Second core module is named as a culturally-sensitive planning & execution, which executes the culturally-sensitive planning algorithms for producing a *culture-competent and application-specific* decision. This decision can therefore be used by the CARESSES robot. Third core module is labeled as a culture-aware human-robot interface, which allow the CARESSES robot to re-configure its verbal and non-verbal style of interaction by depending on the cultural identity of an elderly person.

4. System Integration

4.1. *Conversion Scenario*

Mrs. Yamada has the tendency of being cold, the CARESSES robot that is culturally aware and competent robot can provide a proper service to turn on the air-conditioner upon interacting with her in which she got to know that the temperature in the living room is high. Figure 8 illustrates a scenario that is describing a possible conversation between Mrs. Yamada and the CARESSES robot. The conversation example is demonstrating the interaction between them to change the temperature of air-conditioner setting in the living room. The operation to complete the scenario can be divided into three parts: (i) check the temperature in the living room via temperature sensor; (ii) check the temperature setting of the air-conditioner; and (iii) control the temperature setting of the air-conditioner.

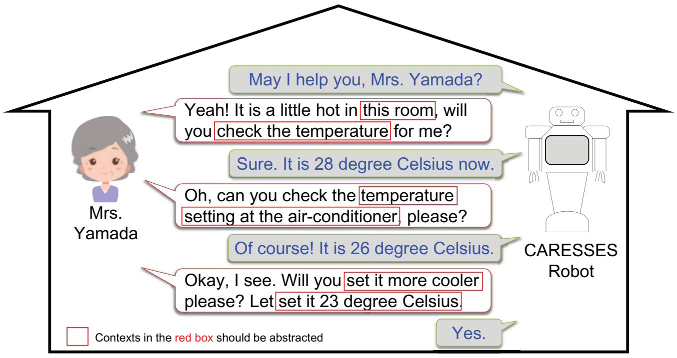

Fig. 8. Example of conversation scenario

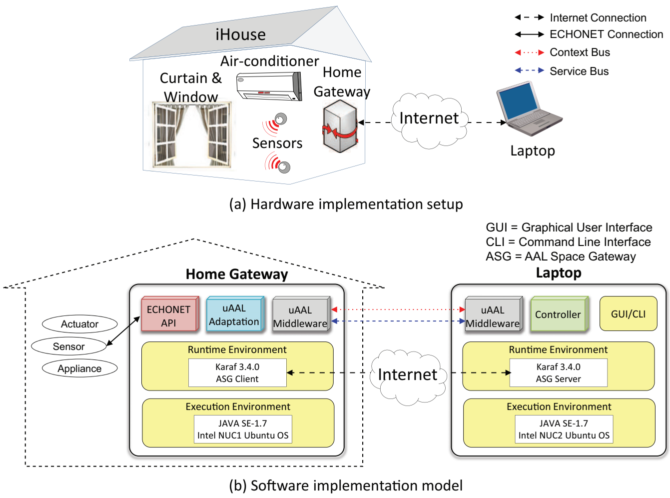

Fig. 9. System-level integration of remote access scenario

4.2. Remote Access Scenario

Based on the three operations in Section 4.1, the system-level integration of uAAL and ECHONET in the *iHouse* has been designed and implemented. At the preliminary stage, the first operation is applied in which the command is made from the uAAL Application layer to read the temperature value from a sensor, which is located in the living room of *iHouse* and then the sensor notifies the room temperature value back to the uAAL Application layer.

The system-level integration of remote access scenario is visualized in Fig. 9. The hardware of remote access scenario involves one laptop, which is located outside from iHouse, and a home gateway and three sensors, which are placed inside iHouse. The hardware and software specifications of the laptop and the home gateway are Intel NUC 6i3SYK with Ubuntu OS 16.04 LTS 64-bit. Meanwhile, the sensor hardware is a Raspberry Pi 2 Model B mounted with temperature sensor and its software setup is Raspbian Jesse. The software implementation model comprised of an execution environment and a runtime environment as depicted in Fig. 9(b). In the execution environment, the Java SE-1.7 is installed for both laptop and home gateway. In the runtime environment, the Karaf 3.4.0 is installed. Then, the laptop and the home gateway are configured as a ASG server and a ASG client, respectively. At the ASG client side, ECHONET API, uAAL Adaptation and uAAL Middleware are built. At the meantime, GUI/CLI interface, controller and uAAL Middleware are constructed at the ASG server side.

The main goal of the system-level integration is to bridge the uAAL Adaptation to the ECHONET for the smart home environment. The operation from the uAAL Application at the ASG server side is handled through a controller. The controller interprets the semantic information according to the communication specification that is built with the service bus or the context bus by matching and filtering the information events, then results a series of information that is required to be send to the uAAL Adaptation. The controller also sends those information events by using the publish-subscribe messaging pattern.

The information events that are extracted in the uAAL Adaptation of home gateway undergo a syntax translation to establish the data communication in between the uAAL-specific and ECHONET-specific specifications. In order to process the function of syntax translation, a database for the list of ECHONET-oriented objects and a repository of uAAL ontologies for the list of objects that is belonging to the uAAL platform.

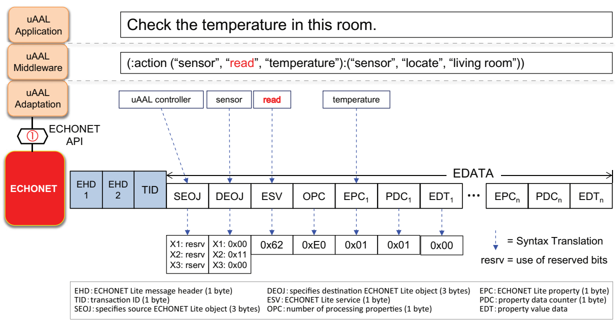

Fig. 10. Syntax translation from uAAL objects to ECHONET objects

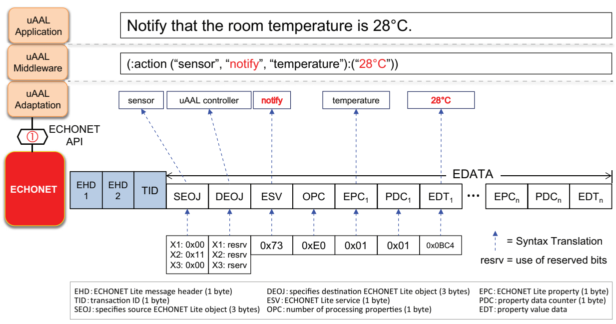

Fig. 11. Syntax translation from ECHONET objects to uAAL objects

4.3. Syntax Translation

The uAAL Application layer that provides several services will delivers commands in way of messages in order to give instructions for interaction with the sensors or actuators inside the smart home environment through the uAAL Middleware. The flow of the uAAL semantic information through the uAAL Middleware defines the service bus or the context bus as the peer-to-peer communication from the uAAL Application layer to the uAAL Adaptation layer. Upon receiving the messages, the message will be translated into objects of uAAL and ECHONET with an aid of uAAL ontologies and ECHONET database, respectively. Thus, the function of syntax translation is carried out the object translation in between the uAAL object and the ECHONET object in the uAAL Adaptation. This syntax translation is essential for realizing the data communication among nodes in between uAAL-specific and ECHONET-specific protocols.

Figure 10 illustrates the syntax protocol translation from the uAAL objects to ECHONET Lite objects for the smart home environment. During this process, the command that is to check the room temperature will be sent from the uAAL Application layer and then the RDF object will extracts the semantic information such as local server, sensor type, operation and predicate to be delivered as the uAAL objects to the ECHONET object. In ECHONET object, each of the extracted uAAL objects will be referred to the defined ECHONET data (EDATA) of ECHONET Lite frame format and translate them one by one accordingly. With the information translated into the required frame format of ECHONET Lite specification, the ECHONET API at the home gateway side will broadcast them. Then, sensors will perform the command operation accordingly. At the same time, sensors will reply with the notification messages together with the required value to the ECHONET API. Figure 11 shows the reverse syntax protocol translation from the ECHONET Lite objects to the uAAL objects. During this process, the information in ECHONET Lite frame format will be extracted and translated into the specified RDF data representation. By collecting the specified RDF information of the temperature sensor, uAAL Middleware will then send those information in the form of messages back to the uAAL Application layer.

4.4. Scenario Ontology

An ontological model is also known as information model to represent real-life information that can be understood by computers. Therefore, the ontology of remote access scenario is shown in Fig. 12. The information knowledge in the uAAL ontologies of uAAL Adaptation is shared in the form of ontologies through the uAAL Middleware in which they can be represented in some standard formal language like the RDF. The scenario ontology in Fig. 12 has been extended from the smart facility module of the skeleton ontology. To realize the remote access scenario, four modules about the laptop, home gateway, sensor, and air-conditioner are added.

4.5. Implementation and Discussion

At this preliminary stage of implementation, two issues are found. First, the newly version of Apache Karaf Container is not comprehensively compatible with the uAAL Middleware. As a result, the publish-subscribe messaging pattern does not work properly. Further investigation on this issue is required in order to ensure the publish-subscribe messaging pattern works smoothly. Second, the information that is stored at the uAAL ontologies is not timely updated. When the number of devices in the smart home environment is increasing, the status information of those connected devices are dynamically changed due to unpredictable circumstances, e.g., unstable communication links, drained battery of sensors, data traffic congestion, and so on.

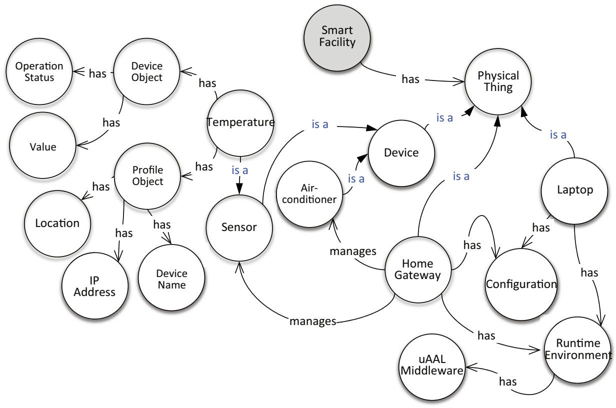

Fig. 12. Ontology of remote access scenario

5. Concluding Remarks

This paper has presented an overview framework on how to bridge in between the uAAL and the ECHONET standard in smart home environment. Further works are required to verify the test and implementation, including the rest of operations. For that purpose, the system integration of CARESSES robot will be considered.

Acknowledgement

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